

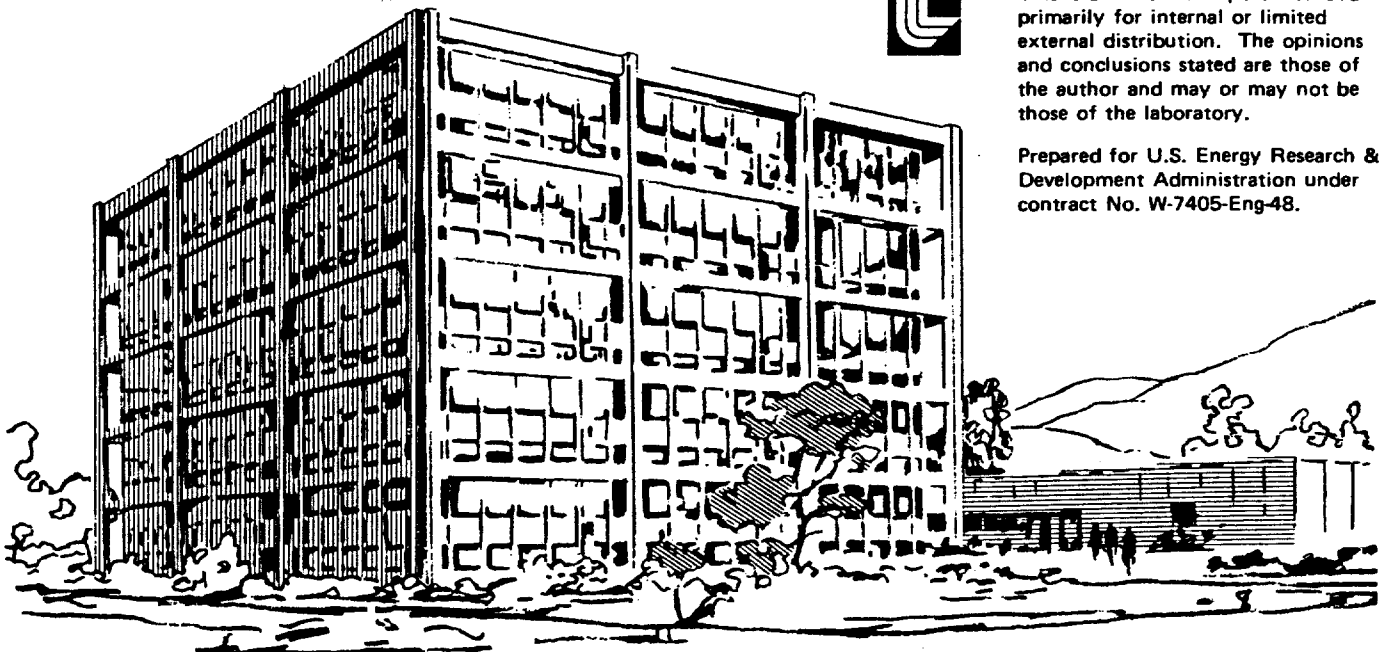
Lawrence Livermore Laboratory

THE SPREADING AND DIFFERENTIAL BOIL-OFF FOR A SPILL
OF LIQUID NATURAL GAS ON A WATER SURFACE

WERNER STEIN

AUGUST 1978

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OF LIQUID NATURAL GAS ON A WATER SURFACE

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August 1978

ABSTRACT

A model for the spreading and evaporation of liquid natural gas (LNG) when spilled on a liquid surface has been developed. The model includes a model for differential boil-off of the LNG constituents. A listing of the code, LNGVG, for making these calculations plus calculational results for an anticipated LNG spill test to be conducted at China Lake, California are included in the documentation.

*

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INTRODUCTION

Liquid natural gas (LNG) is a cryogen with a boiling temperature, at 1 atm., of approximately 111° K. Spillage of LNG on a water surface results in a very rapid spreading into a circular shaped pool. During this spreading process, heat transfer from the relatively warm water to the cold LNG results in boiling of the LNG with a resultant high rate of gas vapor generation.

LNG is composed primarily of methane with small fractions of ethane, propane and nitrogen, see page 5. These constituents have different heats of vaporization and boiling points with the result that they boil off at different rates. This differential boil off during vapor generation results in LNG vapors containing different fractions of constituents than the originally spilled LNG.

A computer program called LNGVG to calculate LNG Vapor Generation and differential boil off has been written. A listing of the code is given in Appendix A. Calculations have been made, using LNGVG, for a spill of 5 cubic meters of LNG in a time of 50 seconds and are described below. These spill conditions are representative of conditions expected during experiments to be conducted at China Lake.

DISCUSSION

The calculations for the spreading of LNG are approached by determining the velocity of the leading edge of the LNG pool. This velocity is determined by considering the outer edge as a density intrusion. The radius of the pool as a function of time is determined by integration of the velocity equation. Spreading occurs until pool break-up occurs.

Pool break-up is assumed to occur when the thickness of the LNG reaches an experimentally determined minimum thickness, due to spreading and evaporation. The break-up is observed to occur at the center of the pool first and spreads radially outward until all the LNG has evaporated.

The rate of evaporation for LNG from a water surface is often determined experimentally and given as a regression rate (i.e., cm./min.). This regression rate represents the sum of the contributions from each of the LNG constituents. The fraction of this regression rate applicable to each of the constituents is determined in the calculation by the relative magnitudes of their heats of vaporization, boiling temperature and volume fraction. This relative fraction of total boil-off for each constituent varies with time and is different from the original volume fraction of the LNG.

LNG SPILL SCENARIO

The phenomena that occur during a spill are described below. The LNG is assumed to be spilled at a certain rate for a finite time.

- (1) Initially the LNG spreads radially at a rapid rate, which decreases as the radius increases. Boil-off of the LNG takes place as soon as the LNG contacts the water surface. Due to the differential boil-off phenomenon, the vapors generated have different volume fractions than the initial LNG. Also, the volume fraction of the LNG constituents of the LNG on the water surface changes due to the differential boil-off.
- (2) The LNG spreads out to a radius large enough to vaporize an amount of LNG equal to the rate of LNG spill. The LNG composition on the water surface continues to change due to differential boil-off until a condition is reached where the rate of boil-off of each LNG constituent equals the rate of spillage of each constituent.
- (3) Steady conditions are maintained until the spillage is stopped. Now, the volume fraction of each constituent in the spilled LNG changes due to differential boil-off and the vapors generated again have

volume fractions different from the original LNG volume fractions.

- (4) The volume of LNG left on the water decreases as vapor generation takes place until the pool begins to break up in the center. Initially just a small circular area of water is visible. This circular area increases with time until the entire mass of LNG has evaporated.

ANALYTICAL RELATIONS

The radius of the LNG spilled on the water surface is given by equation (1): [1]

$$(1) \quad r = 1.35 \left(g \frac{\rho_w - \rho_{\text{LNG}}}{\rho_w} \right)^{1/4} V^{1/4} t^{1/2}$$

where: r = radius

ρ = density of LNG or water (w)

V = volume of LNG on water surface

t = time

The velocity of the leading edge of the LNG is given by differentiating equation (2) with respect to time while holding V constant:

$$(2) \quad \left(\frac{dr}{dt} \right)_{V=\text{constant}} = \frac{1.35}{2} \left[g \frac{\rho_w - \rho_{\text{LNG}}}{\rho_w} \right]^{1/4} V^{1/4} t^{-1/2}$$

The method of applying the above equations was to calculate the spreading for very short time increments using a constant LNG volume during the time increment. After each time increment, the volume remaining was adjusted to account for LNG added during spilling and loss due to evaporation. Thus, the radius after $N+1$ successive time intervals, Δt , is given by:

$$(3) \quad r_{N+1} = r_N + \left(\frac{dr}{dt} \right)_{V=V_N} \Delta t$$

and the volume V_N is given by:[1]

$$(4) \quad V_N = V_{N-1} + [\dot{V} - EV_{N-1}] \Delta t$$

where: \dot{V} = rate of addition of LNG

EV = Rate of evaporation of LNG

In the case of a continuous LNG spill, the maximum radius of the pool is given by:

$$(5) \quad \dot{V} = \pi R^2 K$$

where: R = maximum pool radius

K = LNG regression rate (length/time)

After spillage of the LNG has stopped, the maximum radius, R , attained by the pool is assumed to remain constant. During this condition, evaporation takes place until the average LNG pool thickness, h , equals 0.183 cm.[2] and thereafter pool break-up occurs. Pool break-up initially occurs at the center of the pool and spread radially outward as LNG is evaporated during pool break-up, the LNG thickness is assumed to remain constant at 0.183 cm. This value has been experimentally obtained with other researchers[3] obtaining different values, up to a factor of 3 larger. Using larger values for pool break-up results in pool break-up occurring sooner.

Also experimentally obtained is the rate of LNG boil-off expressed as a regression rate in units of, for example, cm. of LNG per second. A value

of 0.0423 cm. per second^[4] was used in the subsequent China Lake calculation. This rate represents the sum of the regression rates for each of the various constituents of the LNG. The regression rate for any individual constituent, I, is calculated as follows with I = 1 corresponding to methane (CH₄):

$$(6) \quad K = \sum_I \frac{(C_p \Delta T + HVAP)_{CH_4} \rho_{CH_4} FRI(I)A}{(C_p \Delta T + HVAP)_I \rho_I} = \sum_I K_I FRI(I)$$

where K = experimentally determined LNG regression rate

C_p = specific heat

ΔT = number of degrees that the boiling temperature of constituent I is above the LNG boiling temperature.

HVAP = heat of vaporization

ρ_I = liquid density of constituent I

FRI(I) = volume fraction of constituent I in the original LNG

A = unknown regression rate to be solved for.

Solving (6) for "A" and plugging into the below equation (7) gives the regression rate, K_I , of constituent I:

$$(7) \quad K_I = \frac{(C_p \Delta T + HVAP)_{CH_4} \rho_{CH_4} A}{(C_p \Delta T + HVAP)_I \rho_I}$$

The LNG spilled initially on the water contains various volume fractions of constituents. Throughout the calculations a mass balance is calculated for each constituent in the spilled LNG. Addition of constituents to the spilled LNG is determined from the rate of spill and the known volume fractions of the LNG. Loss of constituents from the spilled LNG is by evaporation. The amount evaporated in a time step Δt of constituent I is given by ΔV_I :

$$\Delta V_I = K_I F S \Delta t$$

where: F = volume fraction of constituent I in the LNG pool

S = surface area covered by LNG pool

In the calculations, the mixture of the constituents is always assumed to be homogeneous.

CALCULATIONS

The above relations have been incorporated into a computer code called LNGVG. A listing is provided in Appendix A. Use of this code involves generating an input file called LNGIN which contains the information called for by the read statements 6 and 8. Input variables and their units are described in the comment cards at the beginning of the code. Output is all contained in an output file called LNGOUT.

Calculations for an anticipated spill at China Lake have been made.

The initial conditions for this spill are given below:

Volume of LNG spilled	=	5 meter ³
Rate of LNG spillage	=	5 meters ³ /50 sec.
Volume fraction of constituents		
in the LNG:		
Methane (CH ₄)	=	0.922
Ethane	=	0.0527
Propane	=	0.0112
Nitrogen	=	0.0139
LNG Boiling Temperature	=	111.7°K (201°R)
LNG Regression Rate	=	0.0423 cm/sec (1 inch/minute)
Water Density	=	1,000 Kg/m ³
Initial LNG Density	=	439 Kg/m ³

RESULTS

The results of the calculations for the volume fraction of each constituent in the vapors generated vs. time is shown in Figures 1 through 3. From these figures, one sees that the initial volume fraction of methane and nitrogen in the vapors is greater than the original fractions in the LNG, and the initial volume fractions of ethane and propane are less than the original LNG. The volume fractions in the vapor adjust themselves with time, however, until at 50 sec (spilling stops at 50 sec) the vapors have approximately the same volume fraction as the original LNG. After spilling stops, (time greater than 50 sec) the volume fraction of methane and nitrogen decreases and that of ethane and propane increases continuously until all the LNG has evaporated.

The maximum radius attained by the LNG pool is 28.5 feet at a time of 27.0 seconds. Pool break-up is calculated to occur after 61.5 seconds and total evaporation is completed after 78 seconds.

The total boil-off rate (ft^3/sec) vs. time for this spill is shown on Figure 4.

CODE VERIFICATION

The work done in this study is primarily analytical in nature and has not been compared with experiment.

Comparisons with results of other models [4,5] have been made and are tabulated in Table I. The comparison involves maximum time to evaporate and maximum pool radius for instantaneous spills of 10 m^3 and 1000 m^3 . The calculational results from all three models agree fairly closely.

FIGURE 1
VOLUME FRACTION OF METHANE IN LNG VAPORS

LNG SPILL SIZE = 5M^3
SPILL RATE = $5\text{M}^3/50\text{ SEC}$

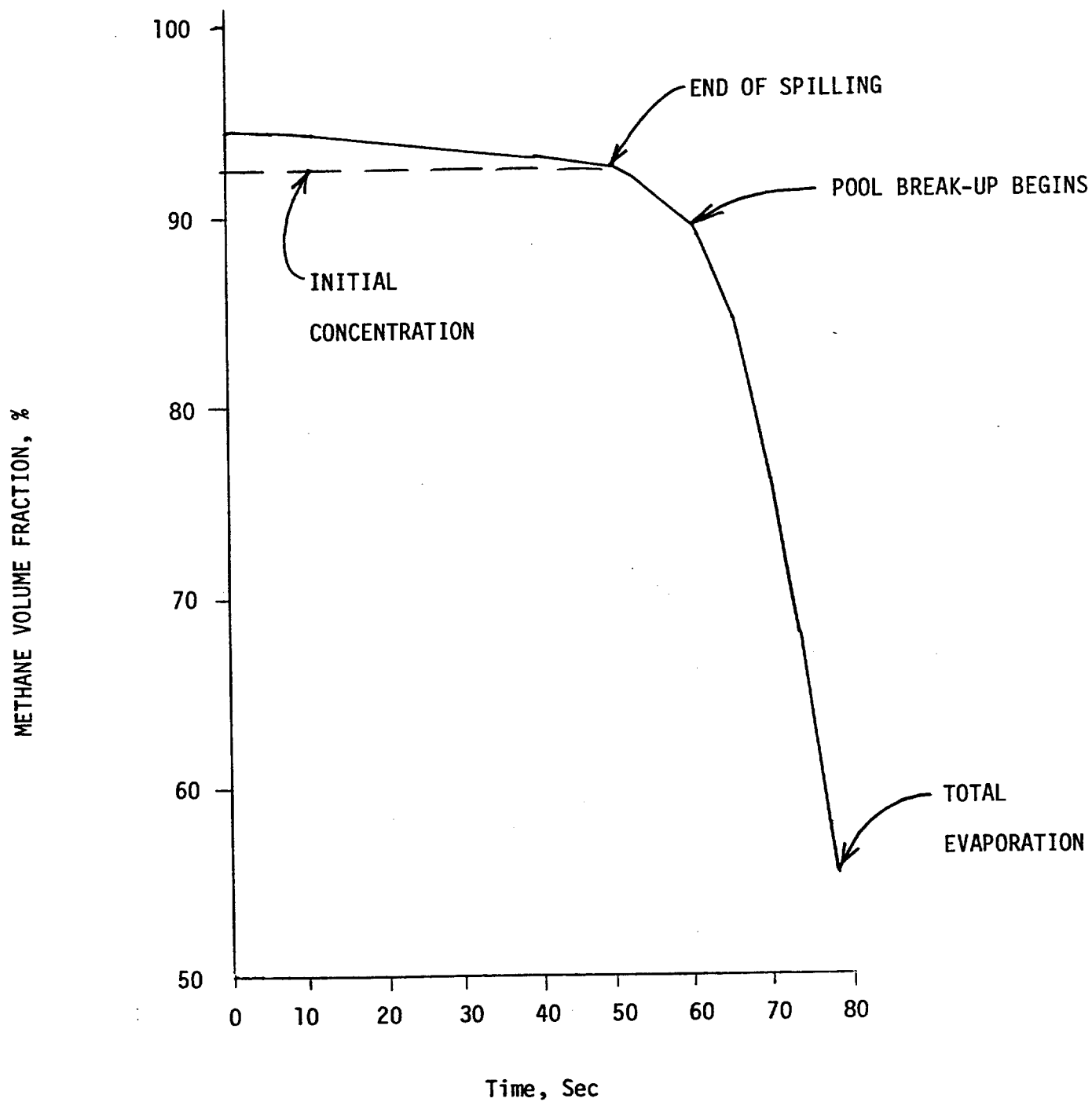


FIGURE 2

VOLUME FRACTION OF ETHANE AND
PROPANE IN LNG VAPORS

LNG SPILL SIZE = 5 M^3

SPILL RATE = $5 \text{ M}^3/50 \text{ SEC}$

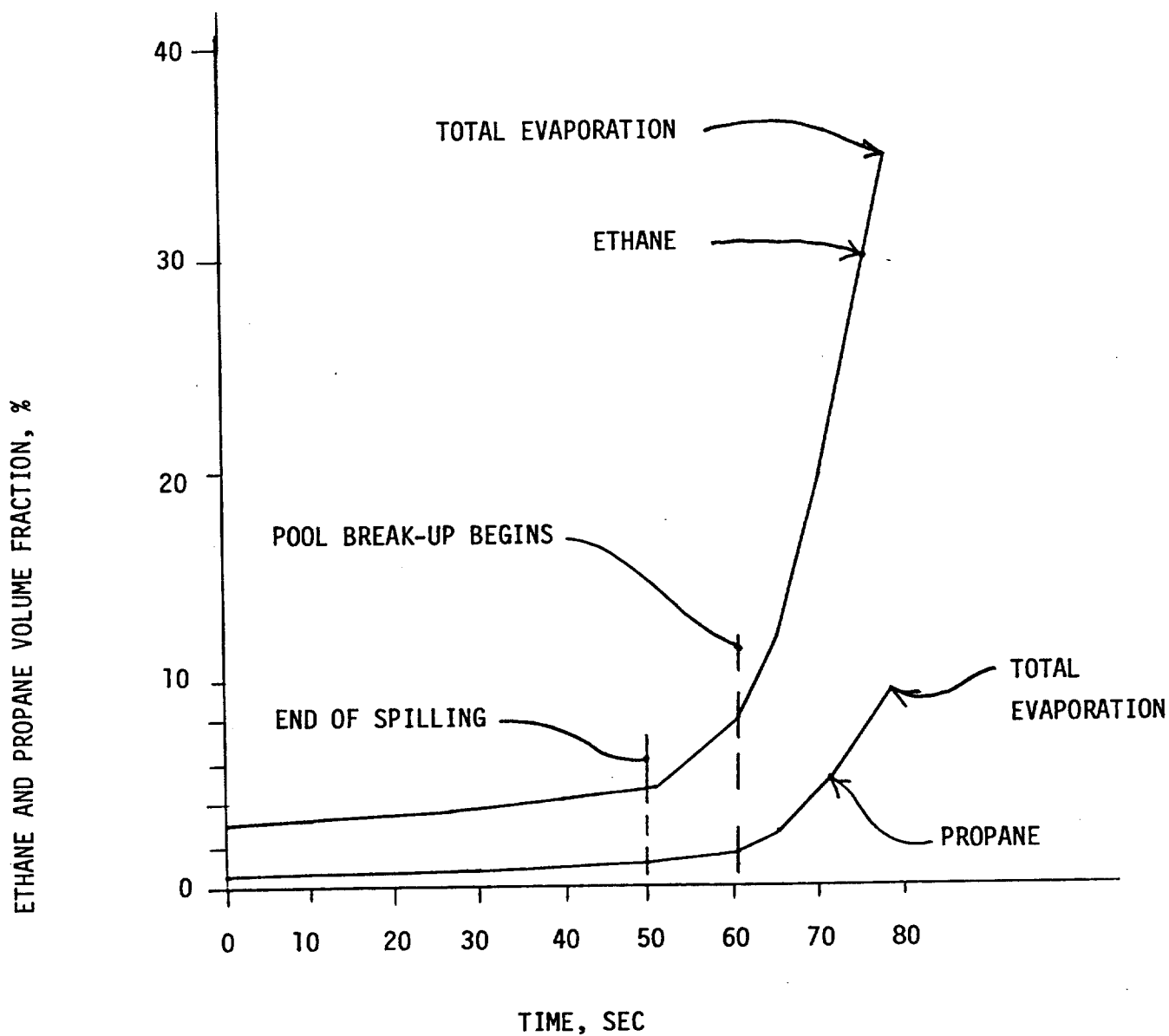


FIGURE 3

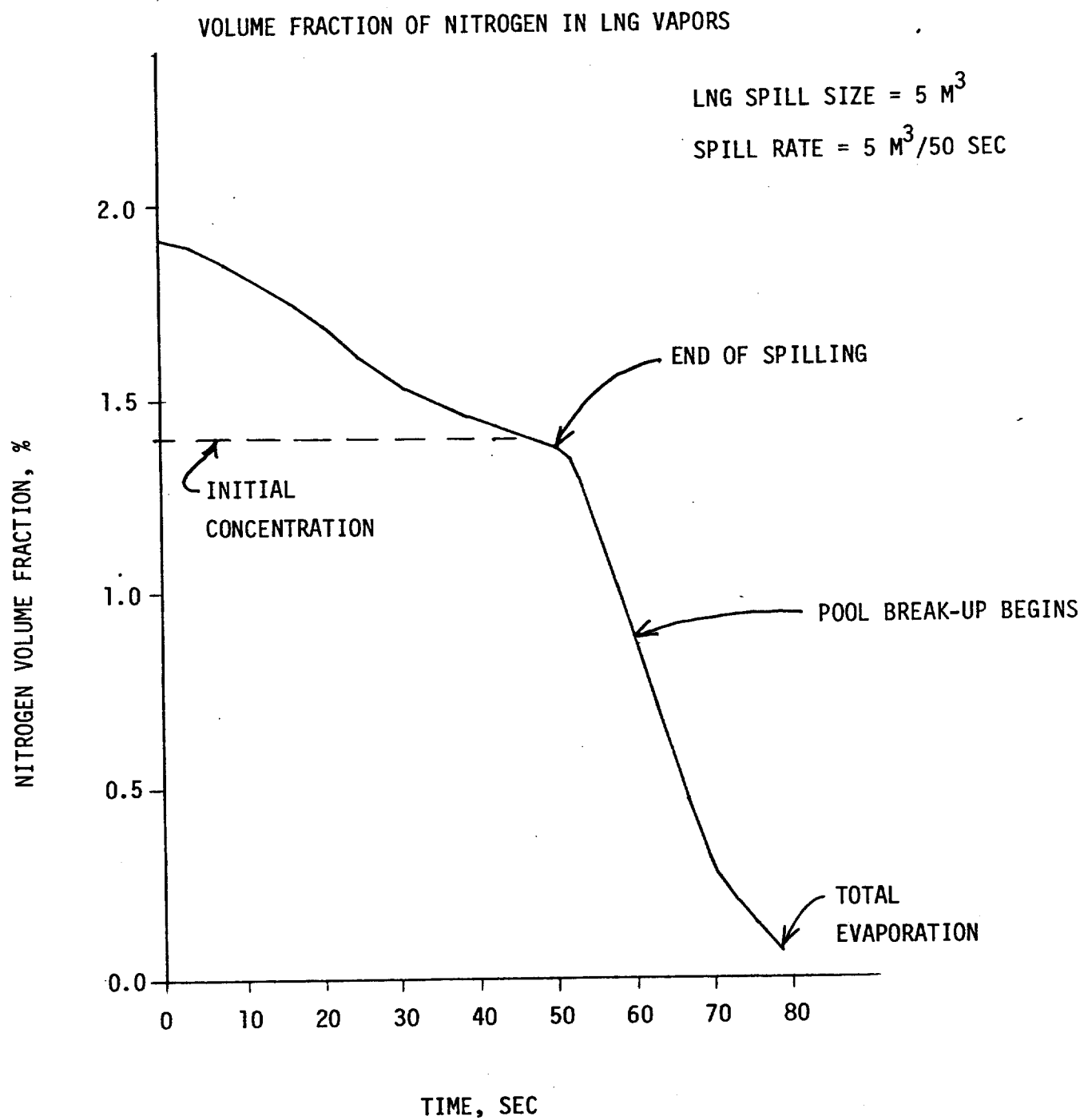


FIGURE 4

BOIL-OFF RATE FROM A SPILL OF 5 m^3 OF
LNG IN A TIME OF 50 SECONDS ONTO A WATER SURFACE

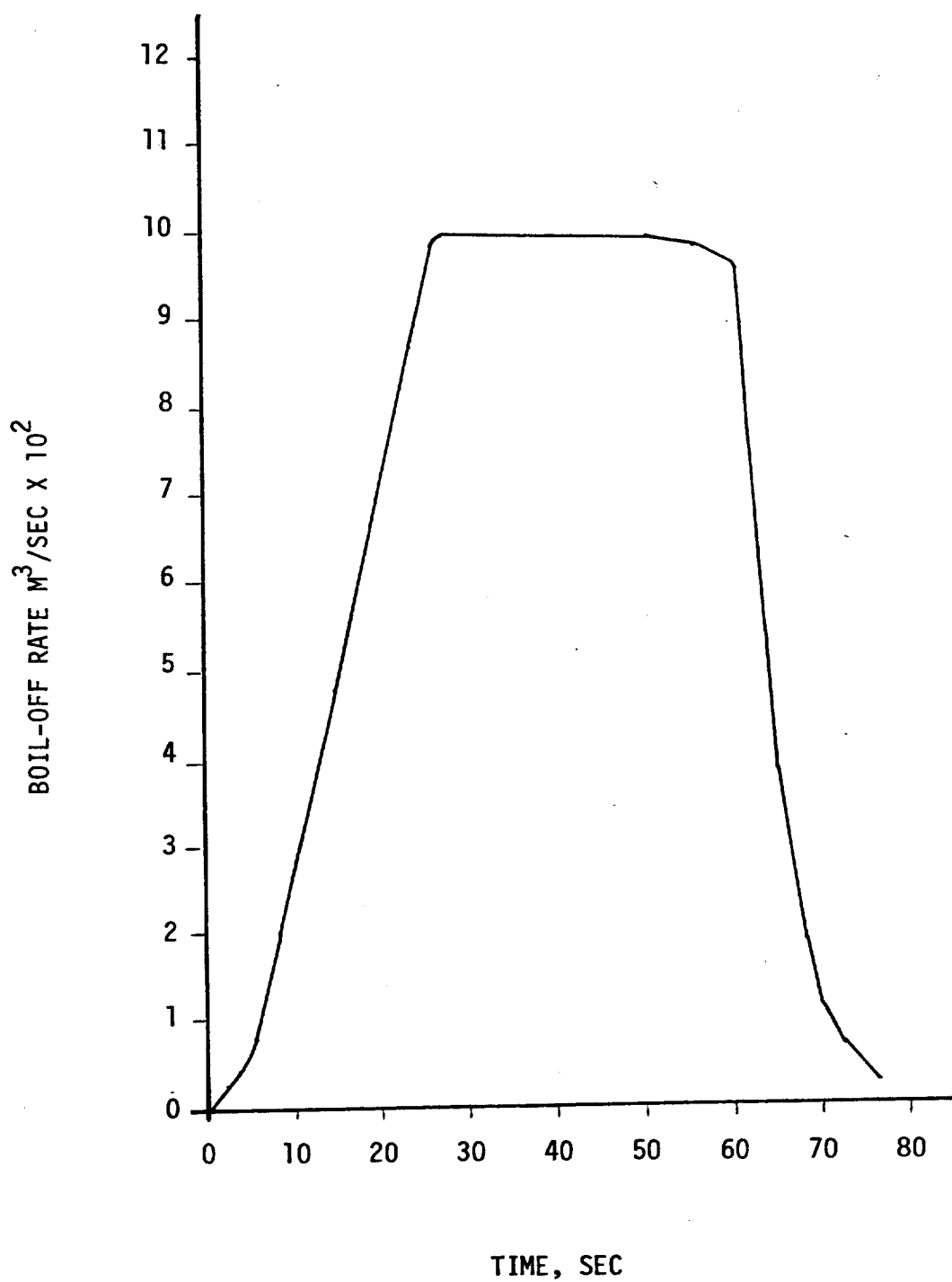


TABLE I

COMPARISON OF MAXIMUM POOL RADIUS, RMAX, AND TIME TO COMPLETE
VAPORIZATION, TMAX, AS PREDICTED BY DIFFERENT ANALYSES

LNG SPILL VOLUME-LIQUID

ANALYSIS	10 M ³		1000 M ³	
	RMAX(M)	TMAX(SEC)	RMAX(M)	TMAX(SEC)
LNGVG	20	44	113	111
FAY ^[5]	16	24	109	108
RAJ ^[4]	20	38	115	120

REFERENCES

1. W. G. May and P. V. K. Perumal, "The Spreading and Evaporation of LNG on Water", ASME Annual Winter Meeting, Nov. 17-22, 1974, N.Y., N.Y.
2. Boyle, G. J., and Kneebone, A., "Laboratory Investigations into the Characteristics of LNG Spills on Water: Evaporation, Spreading, and Vapor Dispersion", Shell Research, Ltd., Report to A.P.I. Project on LNG Spills on Water, Ref. 6Z32, March 1973.
3. G. E. Feldhauer, et al., "Spills of LNG on Water-Vaporization and Downwind Drift of Combustible Mixtures", Esso Research and Eng., Co., Report No. EEGIE-72, Pg. 52; 24 May 1972.
4. P. K. Raj and A. S. Kalelkar, "Fire Hazard Presented by a Spreading, Burning Pool of Liquefied Natural Gas on Water", Paper No. 73-25, Page 8, Western States Section/The Combustion Institute 1973 Fall Meeting.
5. J. A. Fay, "Unusual Fire Hazard of LNG Tanker Spills", Combustion Science and Technology, 1973, Vol. 7, pp. 47-49.

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PROGRAM LNDVG(LNGIN,TAPE2=LNGIN,LNGOUT,TAPE3=LNGOUT)
CALL DEVICE(6HCREATE,6HLNGOUT,50000)
C A = REGRESSION RATE OF CONSTITUENT 1 OF THE LNG, FT/SEC
C AB = USED IN CALCULATING A
C CON = CONSTANT (0.675)
C CP(1) = SPECIFIC HEAT OF CONSTITUENT 1, BTU/LBM/F
C DELRO = DENSITY DIFF. BETWEEN WATER AND LNG ON WATER, LBM/CU.FT.
C DELV(1) = VOLUME OF CONSTITUENT 1 VAPORIZED DURING A TIME STEP, CU.FT
C DENS = SUMMATION OF DENSITY*VOLUME OF EACH LNG CONSTITUENT
C DENS1 = AVERAGE DENSITY OF LNG ON WATER
C DLVS(1) = VOLUME OF CONSTITUENT 1 VAPORIZED PER SEC., CU.FT./SEC
C FR(1) = VOLUME FRACTION OF CONSTITUENT 1 IN LNG VAPORIZED
C FRI(1) = VOLUME FRACTION OF CONSTITUENT 1 IN LNG SUPPLIED
C FRII(1) = VOLUME FRACTION OF CONSTITUENT 1 IN REMAINING SPILLED LNG
C G=ACCELERATION OF GRAVITY - FT/SEC/SEC
C H = AVERAGE HEIGHT OF LNG ON WATER SURFACE
C HBRK = THICKNESS OF LNG AT START OF POOL BREAKUP, FT.
C HVAP(1) = HEAT OF VAPORIZATION OF CONSTITUENT 1, BTU/LBM
C ICONT = 1 MEANS CONTINUOUS SPILL. ICONT=0. FOR NON-CONTINUOUS SPILL
C INST = 1 MEANS INSTANTANEOUS SPILL. INST=0. FOR NON-INSTANTANEOUS SPILL
C LNGIN = NAME OF INPUT FILE
C LNGOUT = NAME OF OUTPUT FILE
C M2 = MULTIPLIER OF PTIM TO OBTAIN PRINT-OUTS AT GREATER TIME INTERVALS
C WHEN 1 IS LARGER THAN N1
C M3 =MULTIPLIER OF PTIM TO OBTAIN PRINT-OUTS AT GREATER TIME INTERVALS
C WHEN 1 IS LARGER THAN N2
C M4 = MULTIPLIER OF PTIM TO OBTAIN PRINT-OUT AT GREATER TIME INTERVALS
C WHEN CALCULATIONS ARE BEING MADE DURING POOL BREAK-UP
C N = TOTAL NUMBER OF INCREMENTS FOR WHICH CALCULATIONS ARE MADE
C N1,N2,N3 = NUMBER OF TIME STEPS AT INCREMENTS OF STEP1,STEP2,STEP3 SEC
C NOSPE = NUMBER OF CONSTITUENTS COMPRISING THE LNG
C NUMBER(1) = NUMBER ASSOCIATED WITH ONE OF THE CONSTITUENTS OF LNG
C PT = TIM
C PT1 = USED IN CALCULATIONS TO SET PRINT-OUT TIME INCREMENT
C PTIM = TIME INTERVAL FOR PRINTOUT OF RESULTS, SEC
C Q(1) = QB(1)*A, FT/SEC
C QB(1) = RATIO OF QBFT(1) TO QBFT(1) TIMES 3.14
C QBFT(1) = HEAT TO VAPORIZE CONSTITUENT 1, BTU/LBM
C R = RADIUS OF LNG POOL ON WATER SURFACE
C RBRK = INTERIOR RADIUS OF POOL BREAK-UP
C RDOT = VELOCITY OF POOL SPREAD, FT/SEC
C REGOR = REGRESSION RATE OF LNG DURING VAPORIZATION, FT/SEC
C RHO(1) = DENSITY OF CONSTITUENT 1, LBM/CU.FT.
C RHO = DENSITY OF WATER, LBM/CU.FT
C RMAX = MAX RADIUS LNG POOL ATTAINS
C RSPIL = RATE OF SPILL OF LNG, CU.FT/SEC
C ROAV = AVG DENSITY OF LNG SUPPLIED, LB/CU.FT.
C SPILT = TIME DURATION OF SPILL, SEC
C STEP = ACTUAL TIME STEP USED IN CALCULATION, SEC
C TDELV = TOTAL VOLUME OF LNG VAPORIZED PER TIME STEP, CU.FT.
C TDLV(1) = TOTAL VOLUME VAPORIZED OF CONSTITUENT 1, CU.FT.
C TDLVS = TOTAL VOLUME OF LNG VAPORIZED PER SEC., CU.FT./SEC
C TIM = TIME FROM START OF CALCULATION, SEC
C TNOT = INITIAL TEMPERATURE OF LNG, DEGREES RANKINE
C TVAP(1) = TEMPERATURE AT VAPORIZATION OF CONSTITUENT, DEGREES RANKINE
C TVOL = TOTAL VOLUME VAPORIZED, CU. FT.
C V = VOLUME OF LNG ON WATER SURFACE, CU.FT.
C VA = USED IN CALCULATIONS TO CALCULATE V
C VOL(1) = VOLUME OF CONSTITUENT LEFT ON SPILL SURFACE, CU.FT.
C VOLI = INITIAL VOLUME OF LNG SITTING ON WATER SURFACE TO START CALC'S

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C IN UNITS OF CU.FT.
4 DIMENSION NUMBER(5),FRI(5),RHO(5),HVAP(5),TVAP(5),CP(5),QB(5),Q(5)
1 VOL(5),QBFT(5),DELV(5),FR(5),FRII(5),DLVS(5),TDLV(5)
C READ INPUT DATA
6 READ(2,1000) INST,ICONT,NOSPE,N1,N2,N3,STEP1,STEP2,STEP3,G,RHOW,
1 RSPIL,SPILT,VOLI,TNOT,REGR,HBRK,ROAV,CON,PTIM,M2,M3,M4
C WRITE OUT INPUT DATA
WRITE(3,1020)
WRITE(3,1030)
WRITE(3,1040) INST,ICONT,NOSPE,N1,N2,N3,STEP1,STEP2,STEP3,G,RHOW,
1 RSPIL,SPILT,VOLI,TNOT,REGR,HBRK,ROAV,PTIM,M2,M3,M4,CON
WRITE(3,1050)
7 DO 20 I=1,NOSPE
8 READ(2,1010) NUMBER(I),FRI(I),RHO(I),HVAP(I),TVAP(I),CP(I)
9 WRITE(3,1060) NUMBER(I),FRI(I),RHO(I),HVAP(I),TVAP(I),CP(I)
20 CONTINUE
AB=0.0
C INITIALIZE PARAMETERS
22 DO 30 I=1,NOSPE
23 QBFT(I)=(CP(I)*(TVAP(I)-TNOT)+HVAP(I))*RHO(I)
24 VOL(I)=FRI(I)*VOLI
25 AB=AB+(QBFT(I)/QBFT(1))*VOL(I)/VOLI
26 QB(I)=QBFT(I)*3.14/QBFT(1)
TDLV(I) = 0.000
30 CONTINUE
WRITE(3,1070)
R=(VOLI/3.14)**0.3333
DELR0=RHOW-ROAV
V=VOLI
H=R
A=REGR/AB
IF(ICONT.EQ.1) RMAX=(RSPIL/(3.14*REGR))**0.5
STEP=STEP1
N=N1+N2+N3
N2=N2+N1
TVOL = 0.0000
PT1 = 0.0000
TIM = 0.0000
PT=PTIM
IDOT = 0
IF(INST.EQ.1) RMAX=9999.
WRITE(3,1080) TIM,N,RMAX,R,H,DELR0,A
35 DO 40 I=1,NOSPE
36 Q(I)=QB(I)*A
WRITE(3,1090) I,VOL(I),QBFT(I),QB(I)
40 CONTINUE
WRITE(3,1100)
C TRANSIENT CONTINUOUS OR INSTANTANEOUS SPILL CALCULATIONS
DO 350 I=1,N
IF(I.GT.N1) STEP=STEP2
IF(I.GT.N2) STEP=STEP3
TIM=TIM+STEP
IF(TIM.GT.SPILT) RSPIL=0.0
IF(R.EQ.RMAX) GO TO 305
303 RDOT=CON*((G*DELR0 /RHOW)**0.25)*(V**0.25) / (TIM**0.5)
304 R=R+RDOT*STEP
IF(R.GE.RMAX) R=RMAX
IF(R.EQ.RMAX) RDOT = 0.000
IF(R.EQ.RMAX) IDOT = 1
305 TDELV=0.0

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VA=0.0
DENS=0.0
DO 310 J=1,NOSPE
306 DELV(J)=Q(J)*VOL(J)*(R**2)*STEP/V
307 VOL(J)=VOL(J)+RSPIL*FRI(J)*STEP-DELV(J)
308 TDELV=TDELV+DELV(J)
VA=VA+VOL(J)
309 DENS=DENS+RHQ(J)*VOL(J)
DLVS(J) = DELV(J)/STEP
310 CONTINUE
TDLVS = TDELV/STEP
TVOL = TVOL + TDELV
V=VA
311 DENS1=DENS/V
DELRO=RHQV-DENS1
313 H=V/(3.14*(R**2))
331 DO 340 M=1,NOSPE
332 FRII(M)=VOL(M)/V
333 FR(M)=DELV(M)/TDELV
TDLV(M) = TDLV(M) + DELV(M)
340 CONTINUE
IF(I.GT.N1) PTIM=PT*M2
IF(I.GT.N2) PTIM=PT*M3
PT1=PT1+STEP
IF(IDOT.EQ.1) GO TO 347
IF(H.LE.HBRK) GO TO 347
IF(PT1.GE.PTIM) GO TO 347
GO TO 349
347 CONTINUE
WRITE(3,1110) I,TIM,R,H,DENS1,RDOT
WRITE(3,1115)
WRITE(3,1120) (J,VOL(J),DLVS(J),TDLV(J),FRII(J),FR(J),J=1,NOSPE)
WRITE(3,1130) V,TDLVS,TVOL
IF(IDOT.EQ.1) GO TO 348
PT1 = 0.0000
348 IDOT = 0
349 CONTINUE
IF(H.LE.HBRK) GO TO 600
350 CONTINUE
RMAX=R
WRITE(3,1200)
WRITE(3,1210) RMAX,H,TIM
PTIM=PT*M4
K=1
602 DO 650 I=K,N
IF(I.GT.N1) STEP=STEP2
IF(I.GT.N2) STEP=STEP3
TIM=TIM+STEP
604 RBRK=(RMAX**2-(V/(HBRK*3.14)))*0.5
RMK=(RMAX-RBRK)/RMAX
IF(RMK.LT.0.01) GO TO 1660
VA=0.0
TDELV=0.0
606 DO 610 J=1,NOSPE
307 DELV(J)=Q(J)*(VOL(J)/V)*(RMAX**2-RBRK**2)*STEP
VOL(J)=VOL(J)-DELV(J)
IF(VOL(J).LT.0.0) VOL(J)=0.0
VA=VA+VOL(J)
TDELV=TDELV+DELV(J)
DLVS(J) = DELV(J)/STEP

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610 CONTINUE
    TDLVS = TDELV/STEP
    TVOL = TVOL + TDELV
    V=VA
    IF(V.LE.0.0) GO TO 1660
611 DO 620 M=1,NOSPE
612 FR(M)=DELV(M)/TDELV
613 FR11(M)=VOL(M)/V
    TDLV(M) = TDLV(M) + DELV(M)
620 CONTINUE
    PT1=PT1+STEP
    IF(PT1.GE.PTIM) GO TO 630
    GO TO 640
630 CONTINUE
    WRITE(3,1220) I,TIM,RBRK
    WRITE(3,1115)
    WRITE(3,1120) (J,VOL(J),DLVS(J),TDLV(J),FR11(J),FR(J),J=1,NOSPE)
    WRITE(3,1130) V,TDLVS,TVOL
    PT1=0.0
640 CONTINUE
650 CONTINUE
1000 FORMAT(3I2,3I5,5F10.4,/,7F10.4,/,2F10.4,3I5)
1010 FORMAT(12,5F10.4)
1020 FORMAT(1H1,"LNG VAPOR GENERATION FOR A SPILL ON WATER - W. STEIN")
1030 FORMAT(/,2X,"INPUT PARAMETERS")
1040 FORMAT(/,5X,"INST=",12,2X,"ICNT=",12,2X,"NOSPE=",12,2X,"N1=",16,
    12X,"N2=",16,2X,"N3=",16,/,5X,"STEP1=",F10.4,2X,"STEP2=",F10.4,2X,
    2X,"STEP3=",F10.4,2X,"G=",F10.4,/,5X,"RHOW=",F10.4,2X,"RSPIL=",F10.4,
    32X,"SPILT=",F10.4,/,5X,"VOL1=",F10.4,2X,"TNOT=",F10.4,2X,"REGR=",
    4F10.4,/,5X,"HBRK=",F10.4,2X,"ROAV=",F10.4,2X,"PTIM=",F10.4,2X,
    5X,"M2=",16,/,5X,"M3=",16,2X,"M4=",16,2X,"CON=",F10.4)
1050 FORMAT(/,6X,1H1,3X,6HFRI(1),4X,6HRHO(1),3X,7HHVAP(1),3X,
    17HTVAP(1),5X,5HCP(1))
1060 FORMAT(5X,12,5F10.4)
1070 FORMAT(/,2X,"INITIAL AND CALCULATED PARAMETERS AT TIME ZERO")
1080 FORMAT(/,5X,"TIM=",F10.4,2X,"N=",16,2X,"RMAX=",F10.6,2X,"R=",
    1F10.6,/,5X,"H=",F10.6,2X,"DELRO=",F10.4,2X,"A=",F10.6)
1090 FORMAT(5X,"I=",12,2X,"VOL(1)=",E12.6,2X,"QBFT(1)=",E12.6,2X,
    1X"QB(1)=",E12.4)
1100 FORMAT(1H1,2X,"TRANSIENT CALCULATIONAL OUTPUT")
1110 FORMAT(/,6X,"I",4X,"TIME",8X,"R",9X,"H",6X,"DENSITY",4X,"RDOT",/,
    116,5F10.6)
1115 FORMAT(15X,"VOL(1)",9X,"DLVS(1)",8X,"TDLV(1)",3X,"FR11(1)",4X,
    1X"FR(1)")
1120 FORMAT(2X,16,3E15.6,2F10.6)
1130 FORMAT(/,1X,"TOTALS",1X,3E15.6)
1200 FORMAT(1H1,2X,"POOL BREAKUP CALCULATIONAL OUTPUT")
1210 FORMAT(/,2X,"RMAX=",F10.6,2X,"HBRK=",F10.4,2X,"TIM=",F10.6)
1220 FORMAT(/,2X,"I=",16,2X,"TIME=",F10.4,2X,"RBRK=",F10.6)
1660 WRITE(3,2000)
2000 FORMAT(5X,"LNG HAS EVAPORATED - PROBLEM FINISHED")
2010 FORMAT(5X,"MAX RADIUS ATTAINED AT TIME =",F10.6)
    CALL EXIT
    END

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